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Efficient Scheduling Scheme Using Connected Dominating Set for Sensed Data Aggregators in Sensor Networks

K. P. Sampoornam[a], K. Rameshwaran[b], a*

[a]*Department of ECE, K.S.R. College of Engg. , Tiruchengode, Tamil Nadu, 637215, India*
[b]*M.A.M.group of Institutions, Tiruchirappalli, Tamil Nadu, 621105, India*

Abstract

A power efficient scheduling scheme extending the life time of sensor nodes on wireless sensor networks has been proposed in this paper. This power efficient sleep scheduling algorithm is based on the connected dominating set approach. This approach first constructs a connected dominating set for parent selection and uses the conjugative sleep scheduler scheme for data aggregation. The re-calculation of connected dominating set when the node is in ON condition and in OFF conditions have been discussed. Finally, the performance of connected dominating set approach is compared with minimum spanning tree approach. By simulating the network with different node density, it is observed that, our proposed approach performs better than spanning tree topology. Whenever a sensor node fails or a new node is added to the network, the conjugative scheduling scheme evaluates the route maintenance. Remaining power levels of nodes have been examined in order to increase the network lifetime.

Keywords: Sensor Networks; Data Aggregation; Conjugate ; Sleeping Schedule ; CDS.

1. Introduction

Wireless Sensor Networks are powerful in that they are amenable to support a lot of very different real world applications. They are also a challenging research problem in Engineering, because of their flexibility. In many WSN applications, individual nodes cannot easily be connected to a wired power supply. Hence, energy efficiency along with life time of a proposed solution has been a very important figure of merit as a long operation time is usually desirable. Realizing such a wireless sensor networks is a crucial step.

Based on the application requirements, designing of wireless sensor networks is not unique. Various sensor nodes that are sensed by the environmental monitoring are selected and placed at a base station where numerous processing can be carried out. Design of the sensor nodes varies accordingly so that in certain cases the possibility of

* K.P.Sampoornam. Tel.: +91-9629377780.
E-mail address: sambu_swasti@yahoo.com.

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recharge or replacement of batteries cannot take place. A common example of sensor networks allows the involvement of hundreds or thousands of sensor nodes from where any amount of information can be collected frequently. For the sake of end-user queries, the information collected can be processed further. The data received can be combined to reduce the message size and further to reduce the communication overhead and energy consumption.

In order to increase the life time of the network by finding an energy efficient routing scheme for accumulating all the data at the sink periodically, which is the main problem discussed in this paper. A simple way of doing that is aggregating the data. An important problem studied here is finding an energy efficient routing scheme for gathering all data at the sink periodically so that the lifetime of the network is prolonged as much as possible [1][2]. The life time of the network can be measured in terms of rounds where a round denotes the difference of the time taken between two sensing activities of the sensor nodes. Studies also show us that a protocol named Minimum Spanning Tree (MST) based routing provides good performance in terms of lifetime when the data is gathered with the help of aggregation. Here the authors proposed a new centralized protocol called PEDAP [3].

The proposed routing approach includes two phases and satisfies the requirements stated above. The first phase discusses the sparse topology over the visibility graph of the network in a localized manner. The second phase, computes the data gathering tree over the edges of the computed sparse topology. All the methods discussed above are based on flooding which is a special packet which uses only the edges of the computed structure. Based on the results obtained the resultant decisions are made.

2. Literature Review

2.1 Routing Protocols

Several routing protocols have been proposed for data gathering without aggregation. Shortest weighted path approach is one of the main methods using several combinations of transmission power, reluctance, hop count, and energy consumption metrics. Classical routing algorithms such as AODV [4] or Directed Diffusion [5] can be considered also for this case. As the transmission distance increases, this method is also not very efficient, since the transmission distances can be quite long and finding a minimum distance chain is very difficult. Results also shows that the protocol PEDAP which routes the packets on the edges of a minimum spanning tree improves the system lifetime when compared to its alternatives discussed by Tan and Korpeoglu [6].

With the help of Prim's MST algorithm [7], PEDAP protocol using the link costs computes the minimum energy cost tree. The MST algorithm helps to design a centralized algorithm that focuses at finding a spanning tree whose maximal degree is the minimum among all possible spanning trees, as the energy consumed at each node depends only on the number of messages received from children nodes, that is, on the number of children. As a result, these trees reduce the load on bottleneck nodes [8].

2.2 *Power Efficient Topologies*

Discussion on energy efficiency of topologies using location information of one-hop neighbors for various topologies is available in the literature. A localized topology that helps to identify the shortest weighted path, called as enclosure graph, has been discussed by Rodoplu and Meng [9]. An edge $\mathbf{e_{ij}}$ is called as the enclosure graph if the direct transmission between nodes i and node j consumes lesser energy than the total energy of all links of any path between them. When shortest weighted path tree uses routing without aggregation, the enclosure graph exhibits a good performance. The topologies that we have concentrated in this work are supersets of Euclidean MST. One among them is the relative neighborhood graph (RNG) [10].The main advantage of using structures like RNG and LMST [11] is that they can be constructed very efficiently in a localized manner. The deletions of nodes and additions of nodes do not change the structure globally. The changes to be performed in the structure are only local changes which can be efficiently computed [12] when a node fails or when a new node is introduced to the network.

3.Efficient Data Aggregation for Sensor Networks with Connected Dominating Set.

This section mainly focuses on formation of a dominating set [13]. The main objective of this paper is to combine the features of Connected Dominating Set (CDS) with conjugative sleep schedule algorithm. Some desirable features are: (1) The formation process should be distributed and simple. (2) The resultant dominating set should be connected and close to minimum. (3) The resultant dominating set should include all intermediate nodes of any shortest path. In order to achieve this, the following algorithm is proposed.

Algorithm

- Create a sorted sequence of edges based on their transmission – reception energy loss.
- Randomly shuffle the sequence of sorted edges.
- Construct a spanning tree based on this shuffled sequence of edges.
- Remove the edges that are in the previously generated spanning tree(s) and obtain a reduced graph.
- Repeat the above procedure on the reduced graph and generate spanning trees until no more spanning trees can be generated.
- The internal nodes of a spanning trees form a Connected Dominating Set (CDS).Select the root node to be the node with the highest energy among the nodes in the CDS and form a rooted directed tree among the CDS nodes.
- The rooted directed tree along with the links from the leaf nodes to their nearest CDS node forms the directed graph tree.
- Repeat the data gathering process for every T rounds and then switch to the next edge disjoint spanning tree in the k- tree list.
- Compare this approach with just a MST- based DG tree – for every round. Choose the node with the highest energy as the root and form a rooted directed tree. The rooted directed tree along with the links from the leaf nodes to their nearest CDS node forms the MST- based DG tree

In order to construct CDS, the following two rules are followed. Consider G and G' are the connected and disconnected dominating set respectively. In G', *v* and *u* are two disconnected vertices .In order to reduce the size of a connected dominating set, Jie Wu et.al. proposed two rules. For this, we first assign a distinct id, *id (v)*, to each vertex *v* in G'. **N [*v*] = N(*v*) U {*v*}** is a closed neighbor set of v, as oppose to the open one N (*v*)

RULE 1: Consider two vertices v and u in G'. If N[v] $\subseteq$ N[u] in G and id(v) < id(u), change the marker of v to F if node v is marked, i.e., G' is changed to G' - {v}.
RULE2: Assume u and w are two marked neighbors of marked vertex v in G'. If $N(v) \subseteq N(u) \cup N(w)$ in G and id(v) = min{id(v), id(u), id(w)}, then change the marker of v to F.

After developing a sparse topology, which is suitable for energy aware rooting, Relative Neighbor Graph (RNG) topology is developed. RNG needs only location information of 1- hop neighbors. It develops Localized Minimum Spanning Tree (LMST), which needs a second message for the sake of informing to local neighbors.

3.1 Data Gathering and Route Maintenance

The job of the sensor node is to periodically sense its nearby environment and tries to generate the data that has to be sent to the sink. Transmission occurs only once in the sensor in a round robin fashion and saves its energy. Then we have to wait for all the data coming from its child nodes to aggregate the data coming from them together with its own data and then the aggregated data is send to the parent node [14]. Whenever the power-aware functions are used while considering route maintenance, there is a possibility of changes to takes place in routing plan and route re-computation [15]. Next we broadcast a new ROUTE-DISCOVERY packet with a new sequence ID. In the node addition process new node broadcasts a HELLO message [3]. The neighboring node updates the local structure and message is being replied to its neighboring node which helps to determine its neighbors.

3.2 Conjugative Power Efficient Sleep Scheduling Scheme

This phase discusses about the Conjugative sleep scheduling scheme in order to efficiently compute routing for the localized energy levels in wireless sensor networks. Better connectivity is being maintained which satisfies the user defined coverage target conjugative to the sensor node and the sink. The main job of sensor nodes is to give the feedback from the sink for the purpose of scheduling activity of the neighbors with the help of residual energy. Sleep scheduler mode reduces randomness in scheduling and the sleeping nodes run in a synchronized schedule. It also maintains a backbone composed of active nodes which deliver data to sleeping nodes when they wake up and bound the communication delay between any two nodes in the order of one duty cycle. Sensor node motion predicts future pickup points where the user expects a query result. In case of pre-fetching, the sensor nodes send pre-fetched messages to future pickup points ahead of time. In the sleep schedule mode, query dissemination is done for collector node which creates a routing tree, to alert the sleeping nodes. The data collection is carried out by the waking up the nodes in time and send data to user through the tree

3.2.1 Conjugative Sleep Schedule operation

The conjugate transpose matrix of a-by-b matrix X with the complex entries is b-by-a matrix X^T which is the transpose. It is an iterative method and can be applied to methods which have enormous data to be handled manually. The resultant transpose matrix is applied with the complex conjugate for each entry. Here, we negate the imaginary parts without affecting the real parts. Defining the conjugate transpose as

$$(X^T)_{mn} = \text{Negation}(X_{mn}) \quad \text{---}(1)$$

where the subscripts denote the m, n-th entry, for $1 \leq m \leq a$ and $1 \leq n \leq b$, and the negation denotes a scalar complex conjugate value. (The complex conjugate of x + iy, where x and y are real's, is x − iy). We say that two non-zero vectors a and b are conjugate (with respect to X) if

$$a\,X\,b = 0 \quad \text{---}(2)$$

Further this conjugate relation is also a symmetric one. (i.e.) If **x** is conjugate to **y,** then **y** is conjugate to **x**.

The operation of the sensor network involves two states: A) A state in which no target is involved. B) A state in which target is involved. Our work involves energy efficient sleep scheduling algorithm for tracking state. We assume that all the nodes follow the random sleep technique. As the sleep pattern is random, all the nodes assume the same toggling period TC at the same time and each node calculates its own random starting time. For instance, a node will wake up and keep active for TC * DC, and then enter the sleep state for TC * (1 - DC).

3.2.2 Algorithm: Conjugative Power Efficient Sleep Scheduling

1. For each node **n** in the tracking neighbors do
2. Compute the distance from the neighbors root node to node **n**
3. Compute t_{start} and t_{end}.
4. Compute the angle θ between the 'root node 'and 'node n' and the instant velocity **v**.
5. Compute DC_{max}.
6. Set the next cycle value as DC_{max} for node **n.**
7. Set no's duty cycle recovery number as Round ($T_{end} - T_{start}$) / TC where Round refers to the rounding function and TC refer to Toggling Cycle.
8. If T_{start} = minimum_sleep_time then
   a. Set node **n** state as SLEEP
   b. Reset node **n** waking up state as T_{start}

3.3 Performance on Sensor Network Density and Power efficiency

The performance measure of distributed adaptive sleep scheduling algorithm in wireless sensor network is performed by applying different density with the help of variation in the sensor nodes. With the help of centralized sleep scheduling algorithm the performance metric is measured. Network lifetime of about 92% is attained along with better energy savings.

4. Experimental Results and Discussion on Power Efficient Scheduler for Sensed Data Aggregation

The experimental evaluation starts from choosing the best parent selection strategy using CDS and then continue the data aggregation with sleep scheduler strategy. Running the experiments with the different topologies for our scenario with three parameters i.e., number of nodes **N**, maximum transmission radius **R** and side-length of the square area **L.** Another parameter defined in this topology is density ***d***, which is defined as the average number of neighbors per node.

4.1 Recalculation of Connected Dominating Set:

There are two different topological conditions such as sensor node in ON condition and node is in OFF conditions are considered for CDS recalculation.

a) Sensor node v's switch on.

When a node v switches on, only its non-gateway neighbors along with host *V* needs to update their status, because any gateway neighbor will still remain as gateway after a new vertex v is added.

The corresponding marking process can be the following:

i) Node v broadcasts to its neighbors about its switch on.
ii) Each host $w \in N(v)$ exchanges its open neighbor set N(w) with its neighbors.
iii) Host *v* assigns its marker m(*v*) to T if there are two unconnected neighbors.
iv) Each non gateway host w E N(v) assigns its marker m(w) to T if it has two unconnected neighbors.
v) Whenever there is a newly marked gateway, host *v* and all its gateway neighbors apply Rule 1 and Rule 2 to reduce the number of gateway hosts.

b) Sensor Node v's switch off.

When a node v switches off, only gateway neighbors of that switched off host need to update their status, because any non-gateway neighbor will still remain as non-gateway after vertex *v* is deleted.

The corresponding marking process can be the following:

i) Node v broadcasts to its neighbors about its switching off.
ii) Each gateway neighbor $w \in N(v)$ exchanges its open neighbor set N(*W*) with its neighbors.
iii) Each gateway neighbor *w* changes its marker m(*w*) to F if all neighbors are pair wise connected.

Since the underlying graph G is connected, we can easily prove by contradiction that the resultant dominating set (using the above marking process) is still connected when a host (gateway or non-gateway) switches off.

Then generate a network with parameters $N = 80, R = 30m,\ L = 120m$. We repeated the experiments on this network with sleep scheduler topologies using spanning tree based parent selection methods. Then compare the efficiency of these two parent selection methods. We conducted experiments with different values of *N*, *R* and *l*.

The life time of the network is obtained for various density set up. The results are tabulated. From the table it is clear that, the Conjugate Sleep Schedule algorithm with CDS extends the life time of the network as the density of the node increases. Both the attributes have been tested with CDS based routing tree construction and without CDS.

Table1: Performance Comparison of Network Life Time

Conjugate Sleep schedule		Conjugate Sleep schedule with CDS	
Density	Lifetime (Sec)	Density	Lifetime (Sec)
10	69	10	78
20	75	20	83
30	79	30	86
40	77	40	79
50	76	50	78

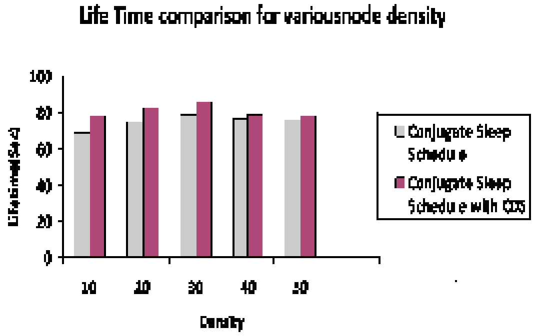

Fig 1. Effect of CDS based Conjugate Sleep Schedule on Network Life Time

Fig1.shows the performance of conjugate sleep scheduler scheme with CDS is better than conjugate sleep scheduler scheme with out CDS for increasing data nodes. As the area enlarges, connectivity decreases, and distances get longer induces the sensed data time reduction.For lower density networks the CSS with CDS perform well when compared to high density networks.

5. Conclusion

The conjugative scheduler scheme for data aggregation in wireless sensor network proposed an energy efficient routing approach. The properties of both connected dominating set and Minimum Spanning Tree for shortest path tree routing schemes are used. Results shows us that the life time increases with the application of CDS even though node density increases.. So sleep schedule algorithm with CDS is more suitable for the application requiring more life time.

This paper combines the features of Connected Dominating Set (CDS) with Conjugative Sleep Schedule Algorithm. To update the connected dominating set, two different topological conditions are considered. An example of changing re-computation period dynamically in a centralized solution can be found in the area size and the maximum transmission range is usually set by the application itself. By the application of distributed sleep scheduling algorithm, performance improved on high density networks.

Based on the simulation topologies and by variation of the sensor nodes to different densities (i.e., 20, 40, 60 and 80) the performance of conjugative power efficient scheduling scheme with and with out CDS is evaluated. As a result of better lifetime, better energy savings achieved in wireless sensor networks.

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